National 5 Chemistry

Unit 3 – Chemistry in Society
Summary Notes

Success Criteria

✓	I am confident that I understand this and I can apply this to problems
?	I have some understanding but I need to revise this some more
×	I do not understand this and I need help with it

I will be successful if I can…		Self-Evaluation		
1	Describe how metallic bonds are formed	✓	?	x
2	Explain why metals conduct electricity	✓	?	x
3	Write balanced chemical equations for the reactions of metals with water, oxygen or acids	✓	?	x
4	Write balanced equations for the reactions of metals with water, oxygen or acids	✓	?	x
5	Describe the reactivity series	✓	?	x
6	Determine the most appropriate extraction method for different metals using the electrochemical series	✓	?	x
7	Describe the process of electrolysis	✓	?	x
8	Balance chemical equations for the extraction of metals	✓	?	x
9	Describe the reduction of metal ions during extraction	✓	?	x
10	Calculate the percentage of a metal in a metal ore using the molecular formula	✓	?	x
11	Determine the direction of electron flow in an electrochemical cell	✓	?	x
12	Discuss the voltage produced by different metals in an electrochemical cell	✓	?	x
13	Describe a reduction reaction	✓	?	x
14	Describe an oxidation reaction	✓	?	x
15	Describe a redox reaction	✓	?	x
16	Write ion-electron equations for oxidation and reduction reactions	✓	?	x
17	Write redox equations	✓	?	x
18	Give two examples of technologies that utilise redox reactions	✓	?	x
19	Name one type reaction used to make plastics	✓	?	x
20	Describe addition polymerisation	✓	?	x

21	Draw the structure of a polymer given the structure of the monomer	✓	?	x
22	Name a polymer given the name or structure of the monomer	✓	?	x
23	Identify the type of polymerisation used to produce a polymer from the monomer(s) used	✓	?	x
24	Give one example of an addition polymer	✓	?	x
25	Explain why fertilisers may be used	✓	?	x
26	State the essential elements used in fertilisers	✓	?	x
27	Write the balanced chemical equation for the Haber process	✓	?	x
28	Name the product formed as a result of the Haber process	✓	?	x
29	State the catalyst used in the Haber process	✓	?	x
30	List the properties of ammonia	✓	?	x
31	Name the acid that can be produced from ammonia	✓	?	x
32	Name the process used to produce nitric acid from ammonia	✓	?	x
33	State the catalyst used in the Ostwald process			
34	Give one use of nitric acid	✓	?	x
35	Calculate the percentage composition of a fertiliser	✓	?	x
36	Describe the effects of radioactive decay on a radioactive element	✓	?	x
37	Name the three types of radiation that can be emitted from a radioactive element	✓	?	x
38	Describe the properties of different types of radiation including mass, charge and ability to penetrate different materials	✓	?	x
39	Identify the type of radiation emitted from a radioactive element	✓	?	x
40	Determine the product formed as a result of radioactive emission	✓	?	x
41	Write nuclear equations to describe nuclear reactions	✓	?	x
42	State the definition of half-life	✓	?	x
43	Determine the half-life of a radioisotope from a graph	✓	?	x
44	Calculate the number of half-lives	✓	?	x
45	Calculate the proportion of a radioactive isotope that has decayed or remains after half-lives have occurred	✓	?	x
46	Give three examples of uses of radioisotopes	✓	?	x

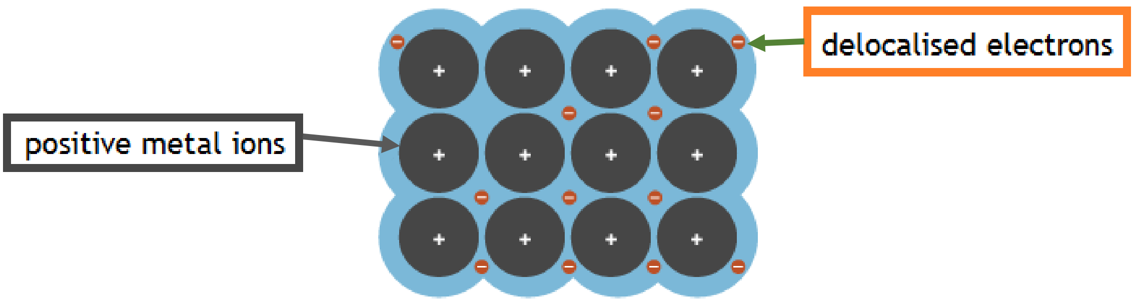
47	Name common lab apparatus for a range of different applications	✓	?	x
48	Use common lab apparatus as part of a range of different experiments	✓	?	x

Key Area 3.1 Metals

Properties of metals

- Metals share two main properties
    1. They are malleable (can change shape)
    2. They conduct electricity

- Metals conduct electricity as they have delocalised electrons, the electrons are free to move
    - the metal atoms form positive metal ions
    - the positive metal ions are electrostatically attracted to the negative electrons
    - the diagram below shows the bonding present in metals



Reactions of metals

- Metals can undergo various reactions to produce new compounds
    - metals can react with oxygen to produce a metal oxide
    - metals can react with water to produce a metal hydroxide and hydrogen
    - metals can react with acid to produce a salt and hydrogen
- When a metal reacts with oxygen a metal oxide is produce
    - A balanced chemical and ionic equation can be written for these reactions
    - For example, the reaction of magnesium with oxygen shown below

Word Equation: magnesium + oxygen $\longrightarrow$ magnesium oxide

Chemical equation: $Mg(s) + O_2(g) \longrightarrow MgO(s)$

Balanced equation: $2Mg + O_2 \longrightarrow 2MgO$

Magnesium is an element. It does not have an ionic formula	Oxygen is a diatomic, non-metal element. It does not have an ionic formula	Magnesium oxide is an ionic compound. It does have ionic formula

Ionic equation: $2Mg + O_2 \longrightarrow 2(Mg^{2+})(O^{2-})$

- When a metal reacts with water a metal hydroxide and hydrogen are produced
    - A balanced chemical and ionic equation can be written for these reactions
    - For example, the reaction of potassium with water shown below

Word Equation: potassium + water $\longrightarrow$ potassium hydroxide + hydrogen

Chemical equation: $K(s) + H_2O(l) \longrightarrow KOH(aq) + H_2(g)$

Balanced equation: $2K + 2H_2O \longrightarrow 2KOH + H_2$

Potassium is an element. It does not have an ionic formula	Water is made of non-metal elements. It does not have an ionic formula	Potassium hydroxide is an ionic compound. It does have ionic formula	Hydrogen is a diatomic, non-metal element. It does not have an ionic formula

Ionic equation: $2K + 2H_2O \longrightarrow 2(K^+)(OH^-) + H_2$

- When a metal reacts with dilute acid a salt and hydrogen are produced
    - A balanced chemical and ionic equation can be written for these reactions
    - For example, the reaction of zinc(I) with hydrochloric shown below

Word Equation: zinc + hydrochloric acid $\longrightarrow$ zinc chloride + hydrogen

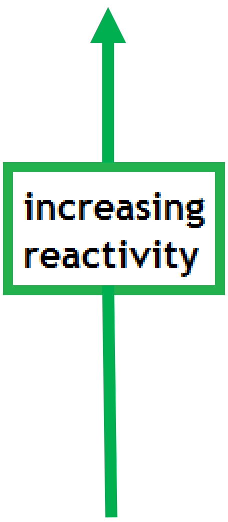
Chemical equation: $Zn(s) + HCl(aq) \longrightarrow ZnCl(aq) + H_2(g)$

Balanced equation: $2Zn + 2HCl \longrightarrow 2ZnCl + H_2$

Ionic equation: $2Zn + 2HCl \quad 2(Zn^+)(Cl^-) + H_2$

Reactivity Series

- Metals can be put in order of reactivity which is shown in the reactivity series
    - **The reactivity series is detailed below**



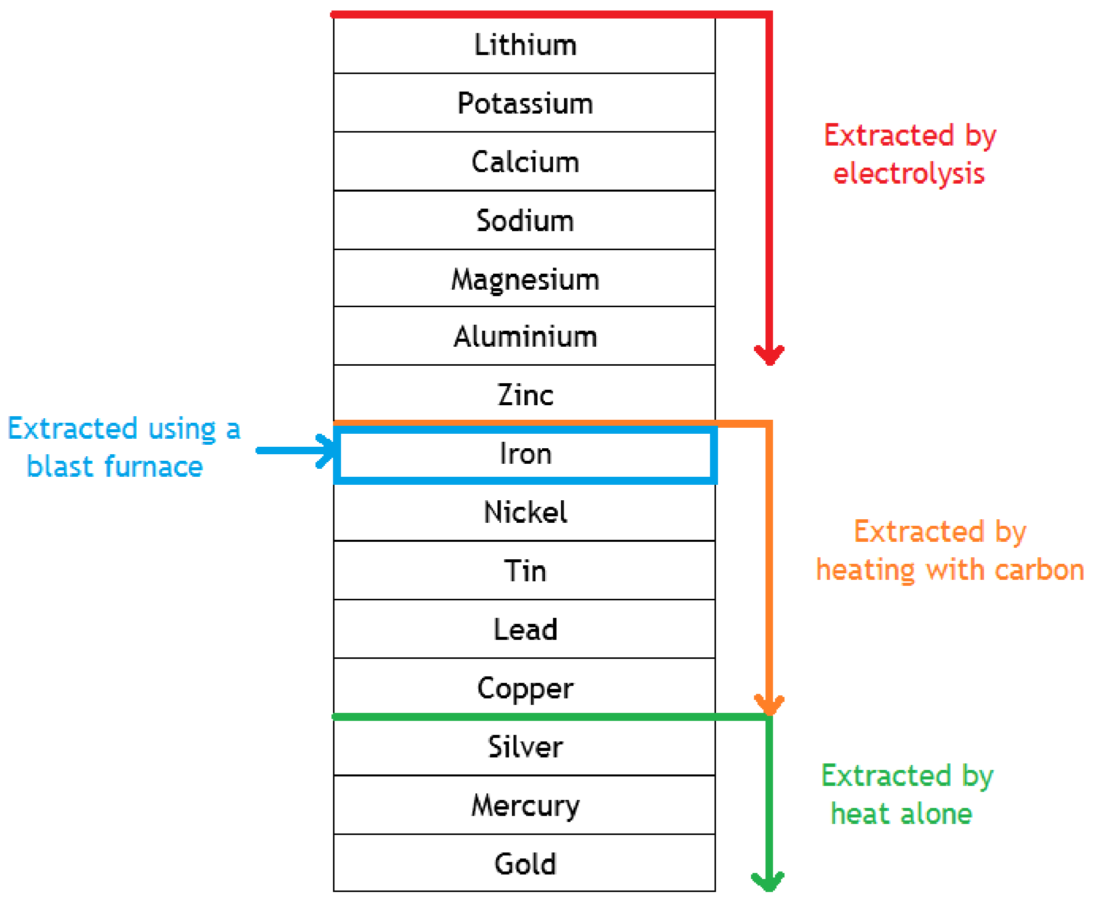
K	**potassium**
Na	**sodium**
Li	**lithium**
Ca	**calcium**
Mg	**magnesium**
Al	**aluminium**
Zn	**zinc**
Fe	**iron**
Cu	**copper**
Ag	**silver**
Au	**gold**

Electrochemical Series

- Metals will lose one or more of their outer electrons to achieve stable electron arrangements
    - This results in the formation of positive ions
- Metals can be put in order of how easily they lose electrons, which is shown in the electrochemical series
    - The electrochemical series is shown on page 10 of the databook
    - Metals high up in the electrochemical series are 'good' at losing electrons
    - Metals low down in the electrochemical series are 'poor' at losing electrons

Extraction Methods

- Ores are naturally occurring rocks that contain metals or metal compounds
    - The metals must be extracted from the ore before they can be used
- There are three main extraction methods used
    1. Heating
    2. Heating with carbon
    3. Electrolysis
- The method of extraction used is dependent on the reactivity of the metal
    - Metals ions in the ore gain electrons to produce metal atoms during extraction
    - The most appropriate extraction method can be determined using the electrochemical series
    - This is summarised in the diagram below.



Composition of Metal Ores

- It is important to calculate the percentage of a metal in its ore
  - The percentage of copper in Tenorite (Cu_2O), an ore of copper, can be calculated as shown below

    Step 1 Write the molecular formula of the ore Cu_2O

    Step 2 Calculate the GFM of the ore = (2 x Cu) + (1 x O)

    = (2 x 63.5) + (1x16)

    = 143g

    Step 3 Percentage mass of copper $= \frac{\text{total mass of metal}}{\text{GFM of ore}} \times 100$

    $= \frac{(2 \times 63.5)}{143} \times 100$

    = 88.9% Copper in Tenorite

  - The percentage of iron in hematite (Fe_2O_3), an ore of iron, can be calculated as shown below

    Step 1 Write the molecular formula of the ore Fe_2O_3

    Step 2 Calculate the GFM of the ore = (2 x Fe) + (3 x O)

    = (2 x 56) + (3x16)

    = 160g

    Step 3 Percentage mass of copper $= \frac{\text{total mass of metal}}{\text{GFM of ore}} \times 100$

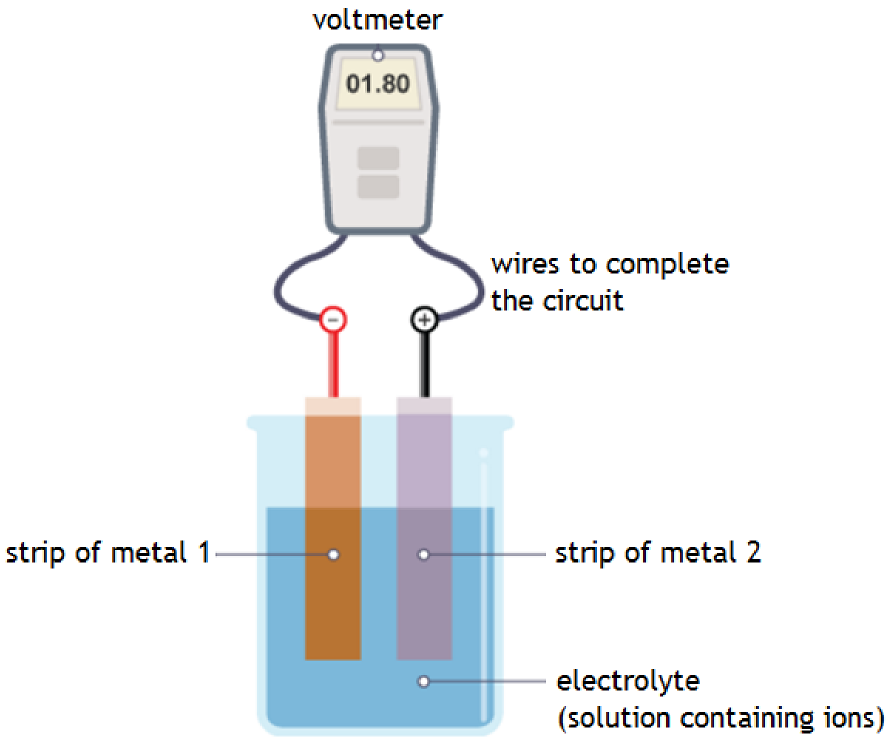
    $= \frac{(2 \times 56)}{160} \times 100$

    = 70% Iron in Hematite

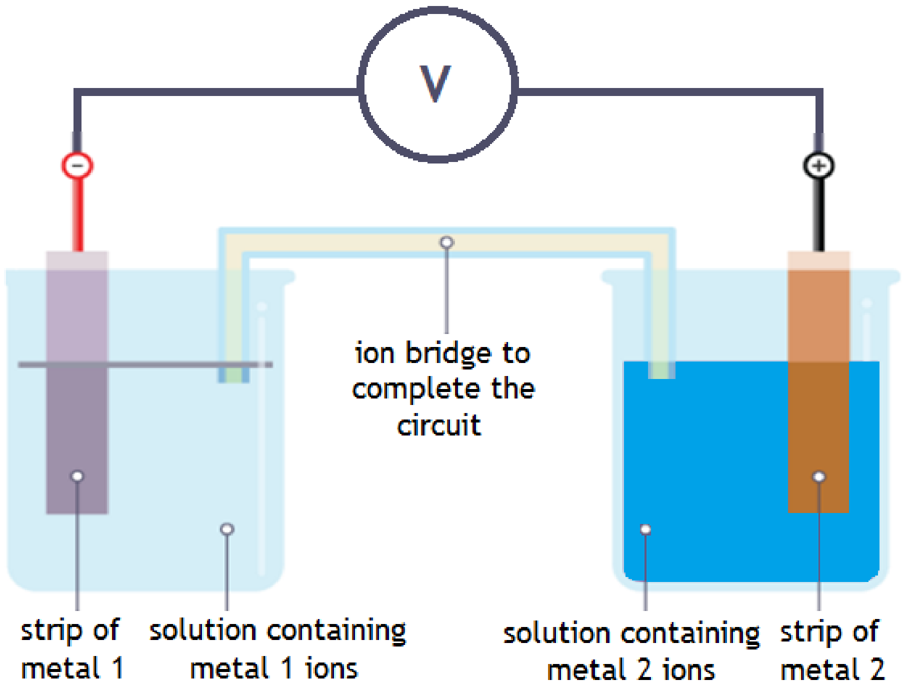
Electrochemical Cells

- An electrochemical cell is an arrangement that generates electricity from a chemical reaction
  - Electrochemical cells can be made up of a single cell or two half cells
  - These cells are shown below

Single Cell



Two Half Cells



Electron Flow

- The electrons in an electrochemical cell flow from one metal to the other
    - The directions of electron flow can be determines using the electrochemical series
    - The electrons will always flow from the metal higher in the electrochemical series to the metal that is lower in the electrochemical series
    - For example, when magnesium and copper are used, the electrons will flow from magnesium (higher) to copper (lower)

Voltage

- The voltage produced by an electrochemical cell can be estimated using the electrochemical series
  - When the metals used are far apart in the electrochemical series, the voltage produced is high
  - When the metals used are close together in the electrochemical series, the voltage produced is low
  - For example, magnesium and copper are far apart producing a higher voltage than zinc and magnesium which are closer together in the electrochemical series

Redox

- An electrochemical cell is an example of a redox reaction
  - A redox reaction involves both a reduction reaction and an oxidation reaction
  - A **reduction** reaction involves an atom or ion **gaining electrons**
    - The ion-electron equations for the reduction of different atoms and ions are given in the databook
  - An **oxidation** reaction involves an atom or ion **losing electrons**
    - The ion-electron equations for the oxidation of different atoms and ions are the reverse of those given in the databook
  - Oxidation Is Loss Reduction Is Gain (**OILRIG**)

Example 1: the ion-electron equation for the **reduction** of magnesium ions is shown below

$$Mg^{2+}(aq) + 2e^{-} \rightarrow Mg(s)$$

The ion-electron equation for the **oxidation** of magnesium is shown below

$$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^{-}$$

Example 2: the ion-electron equation for the **reduction** of iron ions is shown below

$$Fe^{2+}(aq) + 2e^{-} \rightarrow Fe(s)$$

The ion-electron equation for the **oxidation** of iron is shown below:

$$Fe(s) \rightarrow Fe^{2+}(aq) + 2e^{-}$$

- A redox equation for the reaction occurring in an electrochemical cell can be written using the oxidation and reduction equations for the elements present

Step 1 Identify the atom or ion being **reduced** and the atom or ion being **oxidised**

- The element higher in the electrochemical series will be oxidised
- The element lower in the electrochemical series will be reduced

Step 2 Write the **reduction** equation for the atom or ion being reduced

- Copy the equation shown for the atom or ion exactly as shown in the databook

Step 3 Write the **oxidation** equation for the atom or ion being oxidised

- Reverse the equation shown for the atom or ion as shown in the databook

Step 4 Ensure the oxidation and reduction equations have the same number of electrons

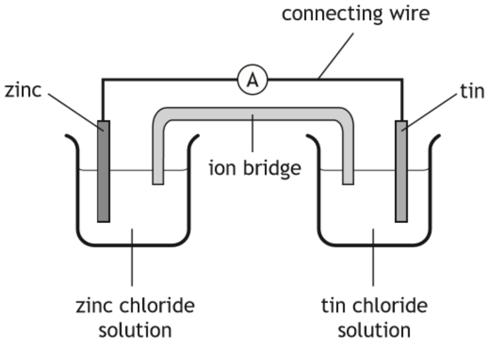
- An ion-electron equation can be multiplied to ensure the number of electrons being lost is the same as the number being gained

Step 5 Combine the reduction and oxidation equations

Step 6 Rewrite the equation eliminating any spectator ions

- Remove any ions or electrons that are the same on both sides of the equation

Example 1 *Write the redox equation for the electrochemical cell shown in the diagram below.*



Step 1 tin is lower in the electrochemical series and will be reduced
zinc is higher in the electrochemical series and will be oxidised

Step 2 $Sn^{2+}(aq) + 2e^{-} \rightarrow Sn(s)$

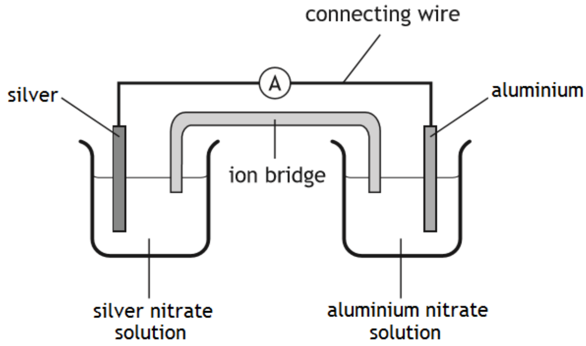
Step 3 $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^{-}$

Step 4 the oxidation and reduction equations have the same number of electrons

Step 5 $Zn(s) + Sn^{2+}(aq) + 2e^{-} \rightarrow Sn(s) + Zn^{2+}(aq) + 2e^{-}$

Step 6 Redox equation: $Zn(s) + Sn^{2+}(aq) \rightarrow Sn(s) + Zn^{2+}(aq)$

Example 2 *Write the redox equation for the electrochemical cell shown in the diagram below.*



Step 1 silver is lower in the electrochemical series and will be reduced
aluminium is higher in the electrochemical series and will be oxidised

Step 2 $Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$

Step 3 $Al(s) \rightarrow Al^{3+}(aq) + 3e^{-}$

Step 4 $Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$ only has one electron so must be multiplied by 3

$3Ag^{+}(aq) + 3e^{-} \rightarrow 3Ag(s)$

Step 5 $Al(s) + 3Ag^{+}(aq) + 3e^{-} \rightarrow 3Ag(s) + Al^{3+}(aq) + 3e^{-}$

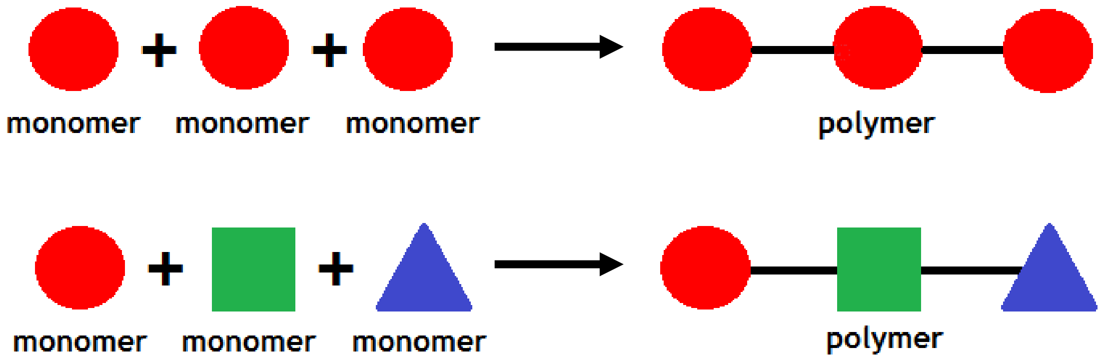
Step 6 Redox equation: $Al\ (s) + 3Ag^{+}(aq) \rightarrow 3Ag(s) + Al^{3+}(aq)$

Uses of Redox reactions

- Fuel cells and rechargeable batteries are two examples of technologies which utilise redox reactions

Key Area 3.2 Plastics

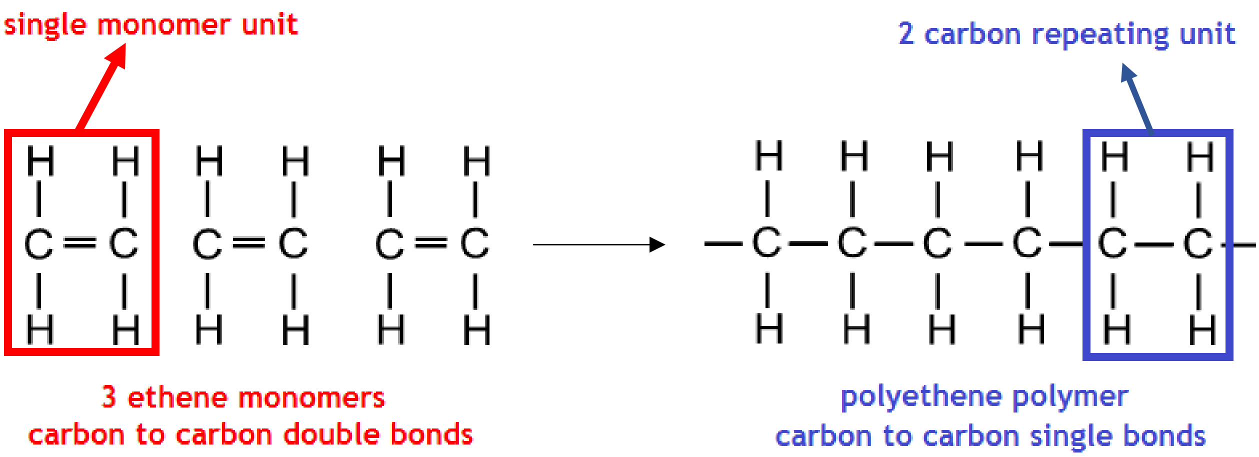
- Plastics are commonly used material to make everyday objects
- Plastics are long chain molecules that are termed polymers
    - Polymers are molecules that formed from multiple monomer units
    - Monomers are simple molecules that can be bonded together to form a polymer
    - Examples are shown below



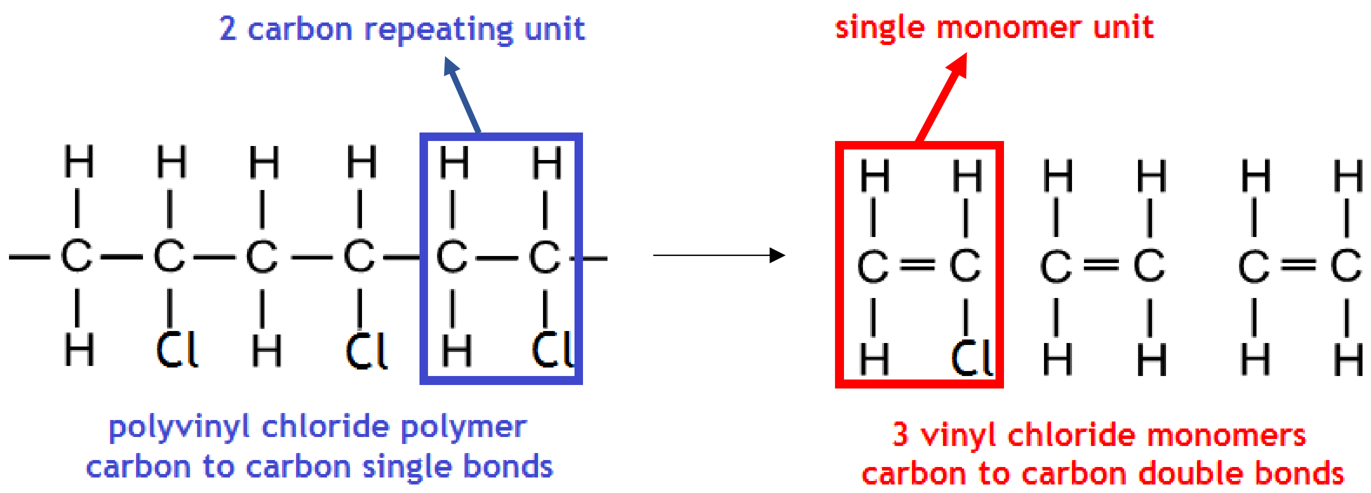
- Plastics can be produced by a process termed polymerisation
    - addition polymerisation is used to produce addition polymers

Addition Polymers

- Addition polymers are formed when monomers take part in an addition reaction
    - The monomers must contain a double bond
    - The monomers bond to create a repeating unit with two carbons
    - The monomer molecules bond by the opening of the carbon to carbon double bonds to give a long chain of carbon to carbon single covalent bonds
    - The reaction of ethene to produce polyethene is shown below



- The monomer used to create an addition polymer can be identified from the structure of the polymer
    - For example, polyvinylchloride shown below



<u>**Key Area 3.3 Fertilisers**</u>

- Fertilisers are used to replace essential elements in soil which has been removed by plants
    - Fertilisers are required due to the increase in population requiring more efficient food production
    - The main three elements are nitrogen (N), phosphorus (P) and potassium (K)
- Fertilisers are added to soil, the dissolve in the water present in the soil
    - The elements can then be up taken by plants through the water
    - To allow fertilisers to be used to enhance plant growth they must be soluble in water
- Fertilisers can be natural or synthetic (man-made)
    - Manure and compost are examples of natural fertilisers
    - Ammonium nitrate, potassium nitrate and ammonium phosphate are compounds commonly used in synthetic fertilisers

Manufacture of Fertilisers

- Ammonia and nitric acid are commonly used in the production of fertilisers
    - The Haber process can produce ammonia
    - The Ostwald process can produce nitric acid from ammonia
    - Ammonia and nitric acid react to produce ammonium nitrate
        - This is a neutralisation reaction

The Haber Process

- The Haber process can produce ammonia for use in fertiliser production
    - The reactants required are nitrogen and hydrogen gas
    - The product is ammonia gas
    - This is a reversible reaction

- Iron pellets are used to catalyse this reaction
- The balanced chemical equation for this reaction is shown below

$$N_2\,(g) + 3H_2\,(g) \longrightarrow 2NH_3\,(g)$$

- Ammonia has a set of distinct properties
  - Ammonia is a colourless gas with a strong, unpleasant smell
  - Ammonia is very soluble in water
  - Ammonia is an alkaline gas

Ostwald Process

- The Ostwald process can produce nitric acid for use in fertiliser production
  - The reactants required are ammonia, water and oxygen
  - The product is nitric acid
  - Platinum is used as a catalyst

Percentage Composition

- The percentage composition of a fertiliser indicates the percentage of each type of element in the fertiliser
- Percentage composition can be calculated using the following steps
  1. Write the molecular formula for the fertiliser
  2. Calculate the gram formula mass of the fertiliser
  3. Write the mass of each element present
  4. Calculate the percentage of a specific element by dividing the mass of the element by the gram formula mass of the fertiliser
- For example, the percentage composition of ammonium nitrate is shown below

Step 1 ammonium nitrate

S	NH_4	NO_3
V	1	1
S	1	1
D	1	1
F	NH_4NO_3	

Step 2 GFM = (2xN) + (4xH) + (3xO)

GFM = (2x14) + (4x1) + (3x16)

GFM = 80g

Step 3 2 x N = 28g

4 x H = 4g

3 x O = 16g

Step 4 %N = 28/80 x 100 = 35%

%H = 4/80 x 100 = 5%

%O = 48/80 x 100 = 60%

- The total percentage should always equal 100%

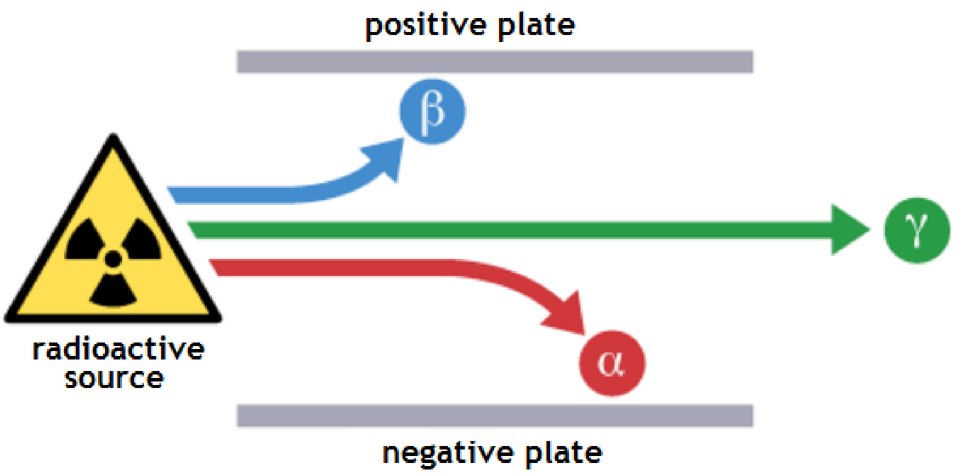
Key Area 3.4 Nuclear Chemistry

- Radiation can be emitted from an unstable atom
    - An atom is unstable when the number of protons and neutrons in the nucleus are not equal
    - The atom emits radiation to become more stable, termed radioactive decay

Types of Radiation

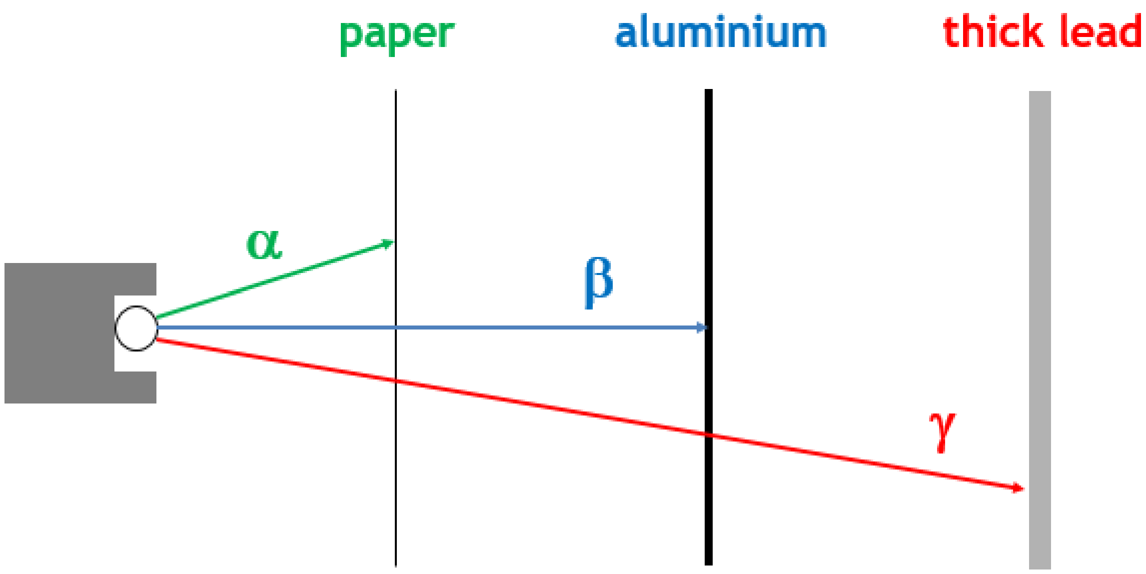
- There are three types of radiation
    - alpha (particle) represented by α
    - beta (particle) represented by β
    - gamma (wave) represented by γ

- The different types of radiation have different properties
    - Behaviour in an electric field
    - Penetrating power
- When passed through an electric field each type of radiation behaves differently
    - alpha particles are attracted to the negative plate
    - beta particles are attracted to the positive plate
    - gamma waves are not attracted to the negative or positive plates
    - The diagram below is a visual representation of this information



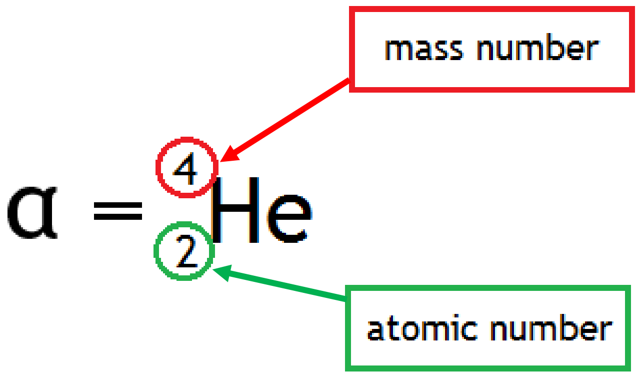
- **Different types of radiation have different abilities to penetrate materials termed their penetration power**
    - alpha has the lowest penetrating power
    - gamma has the highest penetrating power

- The diagram below is a visual representation of this information



Alpha Radiation

- An alpha particle contains 2 protons and 2 neutrons
  - alpha particles have a positive charge
  - alpha particles have a mass of 4 atomic mass units
  - an alpha particle is similar to a helium atom and is represented by the nuclide notation shown below



Emitting Alpha Radiation

- When a radioisotope (an unstable atom) emits an alpha particle, the atom must lose two protons and two neutrons
  - The mass number of the atom is reduced by 4
  - The atomic number of the atom is reduced by 2
  - This results in the type of atom changing, it becomes a different element
- This information can be shown in the form of an equation
  - An example of Americium-241 emitting an alpha particle is shown in the equation below

$$^{241}_{95}\mathrm{Am} \longrightarrow \, ^{237}_{93}\mathrm{Np} + \, ^{4}_{2}\mathrm{He}$$

- An example of Uranium-238 emitting an alpha particle is shown in the equation below

$$\underbrace{{}^{238}_{92}U}_{\text{Uranium-238 radioisotope}} \longrightarrow \underbrace{{}^{234}_{90}Th}_{\text{Thorium-234 radioisotope}} + \underbrace{{}^{4}_{2}He}_{\text{emitted alpha particle}}$$

Beta Radiation

- A beta particle contains 1 electron
  - beta particles have a negative charge
  - beta particles have a mass of 0 atomic mass units
  - a beta particle is similar to an electron and is represented by the nuclide notation shown below

mass number

$$\beta = {}^{0}_{-1}e$$

atomic number

Emitting Beta Radiation

- When a radioisotope (an unstable atom) emits an alpha particle, the atom must gain a proton
  - The mass number of the atom is unchanged
  - The atomic number of the atom is increased by 1
  - This results in the type of atom changing, it becomes a different element
- This information can be shown in the form of an equation
  - An example of Americium-241 emitting a beta particle is shown in the equation below

$$\underbrace{{}^{241}_{95}Am}_{\text{Americium-241 radioisotope}} \longrightarrow \underbrace{{}^{241}_{96}Cm}_{\text{Curium-241 radioisotope}} + \underbrace{{}^{0}_{-1}e}_{\text{emitted beta particle}}$$

- An example of Uranium-238 emitting a beta particle is shown in the equation below

$$^{238}_{92}U \longrightarrow {}^{238}_{93}Np + {}^{0}_{-1}e$$

Uranium-238 radioisotope | Neptunium-238 radioisotope | emitted beta particle

Half-life of Radioisotopes

- The half-life of a radioisotope is the time taken for the sample's activity to fall by half
  - The half-life of a radioisotope can be easily calculated

Calculating Half-life

Example 1

Americium-242 has a half-life of 12 hours. A researcher starter with 10g of Americium-242, calculate the mass of Americium-242 remaining after 48 hours.

Step 1 Calculate the number of half-lives

12 hours: 1 half-life

48 hours: (4 x 12 hours)

: (4 x 1 half-life)

: 4 half-lives

Step 2 Calculate the mass

Starting mass: 10g

After 1 half-life, the mass will be half the original mass = 10g/2 = 5g

After 2 half-lives, the mass will be half the mass after 1 half-life= 5g/2= 2.5g

After 3 half-lives, the mass will be half the mass after 2 half-lives= 2.5g/2 = 1.25g

After 4 half-lives, the mass will be half the mass after 3 half-lives= 2.5g/2 = 0.625g

Step 3 Final answer

0.625g of Americium-242 would be left after 48 hours

Example 2

A radioisotope has a half-life of 4 days. Calculate the fraction of the radioscope that will remain after 12 days.

Step 1 Calculate the number of half-lives

4 days: 1 half-life

12 days: (3 x 4 days)

: (3 x 1 half-life)

: 3 half-lives

Step 2 Calculate the fraction

After 1 half-life, half the mass will remain= ½

After 2 half-lives, half the mass after 1 half-life will remain= 1/2 of 1/2 = 1/4

After 3 half-lives, half the mass after 2 half-lives will remain= 1/2 of 1/4 = 1/8

Step 3 Final Answer

1/8 of the original radioisotope will remain after 12days

Example 3

The mass of a radioisotope falls from 3.8g to 0.475g in 9 hours. Calculate the half-life of this radioisotope.

Step 1 Calculate the number of half-lives

Starting mass: 3.8g

After 1 half-life, the mass will be half the original mass = 3.8g/2 = 1.9g

After 2 half-lives, the mass will be half the mass after 1 half-life= 1.9g/2= 0.95g

After 3 half-lives, the mass will be half the mass after 2 half-lives= 0.95g/2 = 0.475g

Step 2 Calculate time taken

3 half-lives required to reach desired mass of radioisotope

3 half-lives: 9 hours

1 half-life: (9 hours/3 half-lives)

: 3 hours

Step 3 Final Answer

One half-life for the given isotope takes 3 hours

Uses of Radioisotopes

- Radioisotopes have a variety of uses
  - Iodine-131, molybdenum-99 and cobalt-60 can be used in the medical industry
  - Carbon-14 can be used to date materials (carbon dating)

Key Area 3.5 Chemical Analysis

- Identifying common lab apparatus and describing their applications is extremely important
- Some pieces of common lab apparatus are listed below

  - conical flask
  - beaker
  - measuring cylinder
  - delivery tube
  - dropper
  - test tubes/boiling tubes
  - funnel
  - filter paper
  - evaporating basin
  - pipette with safety filler
  - burette
  - thermometer